

Band Structure of Ni(100) versus Permalloy(100).

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INTRODUCTION

The magnetic characteristics of permalloy ($\text{Ni}_{0.8}\text{Fe}_{0.2}$) make this a material widely used in data storage technology. Sensors for hard disk reading heads have been using anisotropic magnetoresistance (AMR) of permalloy or giant magnetoresistance (GMR) of permalloy/Cu/Co thin films. It also exhibits an unusually short scattering length for minority spins.¹ Yet, only a few electronic structure studies have been published for permalloy, and many questions related to the unusual spin scattering remain open, e.g., the nature of the scattering states introduced by the Fe impurity. We have mapped the valence band and the Fermi Surface (FS) of clean Ni(100) and epitaxial Permalloy(100) and compare the momentum distributions. They differ, both in the $3d$ band and at the Fermi level. These differences are discussed in the context of the electronic and magnetic properties, particularly regarding possible minority spin scattering states.

EXPERIMENTAL DETAILS

The experiment was performed at the Advanced Light Source using the high flux and small spot size of the undulator Beamline 8.0. The accurate room temperature FS measurements were achieved by employing the Ellipsoidal Mirror Analyzer (EMA), an imaging photoelectron spectrometer² which allow one to collect a total of 5×10^6 image points at different angles, photon and electron energies. The overall energy resolution was determined to be better than 0.5 eV, and the angular resolution 1.6° .

The Ni(100) single crystal used was cleaned *in-situ* by sputtering and annealing checking that the pressure on the chamber was always better than 1×10^{-9} mbar. The cleanness was monitored by X-ray synchrotron radiation photoelectron spectroscopy, surveying especially the amount of carbon and oxygen. The imaging process was done in a chamber where the pressure was better than 5×10^{-11} mbar, certifying once more the cleanness of the sample. We evaporated *in-situ* Permalloy from a thick wire via e-beam evaporation until the Ni was completely covered, controlling the coverage with the $\text{Fe}_{3p}/\text{Ni}_{3p}$ photoemission intensity ratio. A post annealing at 300°C was performed to order the Permalloy.

RESULTS AND DISCUSSION

By tunneling the photon energy we are able to probe every point in k-space between X(300) and $\Gamma(400)$ and measure the band structure at these high symmetry points of the Ni(100) and the Permalloy. In figure 1 we show the symmetrized and normalized images of the Ni valence band taken at constant photon energy ($h\nu=105.5$ eV) and across the Fermi edge. Each image corresponds to an isoenergetic slice of the momentum space cut around the high symmetry point X(300) of k-space. As we can appreciate, the intensity of the features changes substantially with the selected kinetic energy (KE) of the photoelectron, proving the importance of a correct KE selection for the FS mapping. In our case, and taking advantage of the short collecting time of our analyzer, we acquired many images across the Fermi edge, and choose for our analysis the one that, at lower photon energy, still has the FS structure.

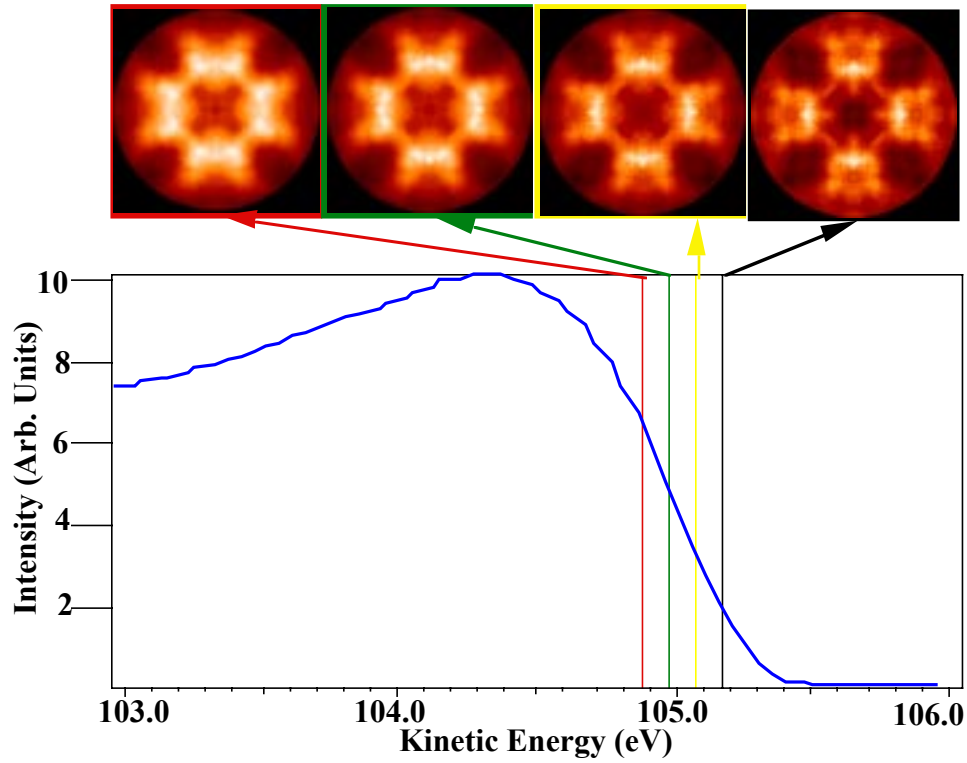


Figure 1 X-ray photoelectron spectroscopy curve of the Ni Fermi edge at $h\nu=105.5$ eV and the isoenergetic maps at different kinetic energies.

The whole Brillouin zone was mapped out by collecting images at different photon energies, every 5 eV from 105 eV to 205 eV, and paying special attention to the high symmetric points of the k-space. All the data –Ni and Permalloy– were taken at exactly the same conditions (geometry, band pass offset...). In figure 2 we show the Fermi Surface of the Ni and the Permalloy at three different high symmetry points of k-space. We note that at the photon energy chosen the EMA displays not only the first Brillouin zone but also part of the second Brillouin zone. Therefore, during the analysis we need to zoom in on the figures to see in detail the Fermi surface structure. In figure 3 we show the Fermi surface of the Ni and Permalloy selecting only the first Brillouin zone at the $\Gamma(400)$ cut.

The main goal of this project was to find the derivative states of the Fe in the Ni matrix. According to the previously measured and calculated band structures of Ni,^{1,3} a spin splitting of the photoelectrons coming from the Σ band should be visible near the Fermi level. This splitting appears near around the middle point between Γ and K. The difference in conductivity of majority and minority spins in Permalloy (i.e., a difference in the lifetime) is due to an increase of the minority spin scattering states.¹ Consequently an extra density of states should be visible were the minority band crosses the Fermi level (separate from the majority), i.e. at the above-mentioned point of the k-space.

Looking figure 3, we see an increase of the density of states around the middle point between Γ and K. Therefore the data support the idea of an extra density of minority states at the E_F responsible of the short path length of the minorities.

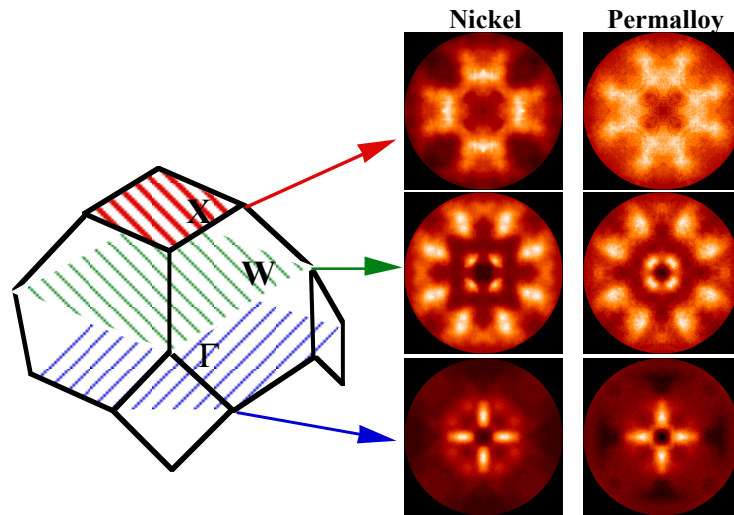


Figure 1 First Brillouin Zone (FBZ) of a FCC crystal with the cuts at high symmetric points and the experimental Fermi Surface of these planes for the Ni and the Permalloy.

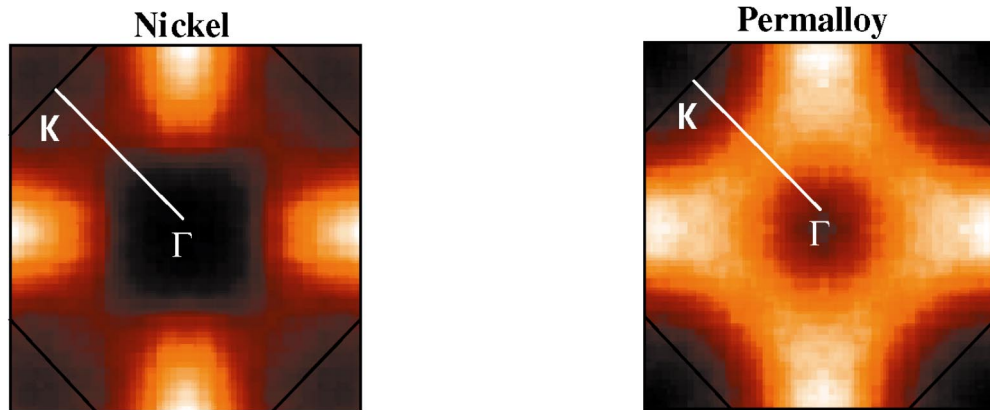


Figure 2 Fermi Surface and first Brillouin zone of the Ni and the Permalloy at the $\Gamma(400)$.

ACKNOWLEDGMENTS

N.Franco is support by the Spanish Education and Culture office under a F.P.I. contract PF-98-33501134. C. Bostedt acknowledges a fellowship from the German Academic Exchange Service DAAD in the HSP-III program. The work is supported by the US-DOE, BES Material Sciences under contract W-7405-ENG-48, LLNL.

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